Studies in Spicule Formation.

VIII.—Some Observations on the Scleroblastic Development of Hexactinellid and other Siliceous Sponge Spicules.

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With Plate 7.

THE contents of the present paper, though brief, represent the results of a year's careful inquiry into the manner in which the spicules of siliceous sponges are produced by the silicoblasts of the organism. This subject having already attracted so much attention from spongologists, most of my results necessarily have been to a large extent merely confirmatory of those obtained by previous workers, and these, of course, I shall mention as briefly as possible. A few of my results, on the other hand, are new, and in one or two instances corrective of former work.

My material has consisted of typical examples of both siliceous groups of sponges—the Triaxonida (Hexactinellida) and Tetraxonida (Tetractinellida and Monactinellida). Some of my specimens have been prepared by the osmic acid and picro-carmine method, already described in previous Studies, and others (the majority) with borax-carmine. The former is the better method. The Monactinellida (viz. young portions or buds of Tethya lyncurium, Hymeniacidon sanguinea, Halichondria panicea, Esperella lingua, Siphonochalina coriacea, Axinella polypoides,

Suberites domuncula, Microciona atrasanguinea,
Cliona sp. and Ectyon ovoides) and Tetractinellida
(viz. young portions of Geodia gigas, Corticium cande-
labrum, Thenea muricata, Stelletta carbonaria,
and Chondrilla nucula) were obtained partly from
Naples and partly from Plymouth; the Hexactinellida (viz.
young portions or buds of Rossella podagrosa, Kpk.,
R. antarctica, Ctr., Anoxycalyx ijimai, Kpk., Anaulo-
soma schulzei, Kpk., Hyalascus hodgsoni, Kpk., and
Aulorossella longstaffi, Kpk.) were in greater part
supplied to me from the British Museum (the "Discovery"
material) at the suggestion of R. Kirkpatrick, Esq.,[1] and
by permission of Professor Sir E. Ray Lankester, and
the rest (viz. young portions of Euplectella marshalli,
Acanthascus cactus, and Crateromorpha meyeri)
were sent to me at my request by Professor Ijima from
Tokyo. I wish to thank Sir E. Ray Lankester, Mr. R.
Kirkpatrick, and Professor Ijima for so kindly assisting
me in this essential; I also wish to express my indebtedness
to Professor Dendy for his ever-ready aid in connection
with spicule nomenclature, for references to the literature of
the subject, and for kindly reading over the manuscript of
this paper.

Hexactinellida.

The scleroblastic formation of hexactinellid spicules has
hitherto, so far as I know, been studied solely by Ijima (**15,
16**) and by Schulze (**31**), and their results have been included
in three sumptuous monographs on hexactinellid sponges pub-
lished in 1901 and 1904. Ijima has described and figured
several developmental stages of the hexasters and one or two
other types of hexactinellid spicules in Euplectella mar-
shalli and Rhabdocalyptus capillatus; Schulze de-
scribed and figured the scleroplasmic investment of certain

[1] Mr. Kirkpatrick has recently published a systematic description of these
sponges obtained by the National Antarctic Expedition (**1**).

spicules, which are adult, or nearly adult, in Trichasterina borealis.

Notwithstanding the large quantity of material which has been placed at my disposal and my thorough examination of this material, I have been very little more successful than the two investigators just named in discovering the early stages in the development of hexactinellid spicules.[1] The earliest stage which I have found is indeed somewhat younger than that figured by Ijima, but it throws very little, if any, extra light on the question as to the condition of the scleroplasm at the time of origin of the spicule and as to the early morphogenesis of the spicule itself. The young stages which I have figured were present in Rossella podagrosa, Kpk., the histology of which species was comparatively well preserved. I have only figured the scleroplasmic investment of spicules from this and the allied species, R. antarctica, because in the other genera which I have studied the spicules were in precisely the same condition.

Ijima's remarks on the scleroplasm in connection with the young spicules described by him are as follows:—"A hexaster begins its development as a hexactin. . . . The hexradiate principals, during the entire period of development of both the floricome and the graphiocome, are imbedded in a body of protoplasmic substance, enclosing a crowded number of nuclei. This nucleated substance may not improperly be called the scleroblast-mass. . . . At first, so long as the terminals are yet undeveloped or are very short, the mass may be said to present a more or less octahedral shape, with somewhat concave surfaces and with rounded corners. In it the three axes of the principals are disposed similarly to the axes in a crystal octahedron, the outer ends of the principals coming up very close, but I think normally not quite, to the surface at the six rounded corners. The mass may otherwise be described as having its surface raised into six, radially directed, hump-like protuberances by the six prin-

[1] It is worth remarking that the buds of my hexactinellids contained fewer young spicules than the older portions of the sponge body.

cipals contained within. Later, after the terminals have considerably advanced in growth, the scleroblast-mass appears at the centre of the developing hexasters as a more spherical body, not unlike a berry, on account of the aggregated nuclei." "Not a trace of cell-outlines is discernible around them [the aggregated nuclei], which fact makes me believe that the scleroblast-mass represents a syncytium." And, referring to the prevalent but mistaken notion that the scleroblast nuclei change their position in order to superintend the process of deposition in different regions of the spicule, Ijima remarks :—"Certain it seems that, during the growth of the terminals, no nucleus moves away from its group around the spicular centre. At least I could gather no evidence pointing to such a movement. It is true that, after a certain period in the growth of terminals, a variable number of nuclei is met with right away, or in close proximity to, these. However, they are altogether so inconstant in number and indefinite in position that it is exceedingly questionable if they have anything to do with the building up of the terminals." My figures confirm all the preceding remarks. Fig. 1a depicts a stage in which the terminals have not nearly reached the surface of the spherical syncytium, and which is, therefore, younger than any figured by Ijima. Ijima goes on to remark concerning the "great probability . . . that each growing terminal is completely invested by an extremely thin protoplasmic layer, specialised physiologically at least as the secretive matrix, and standing in direct continuity with the scleroblast-mass. Such a layer, however, could never be clearly demonstrated."[1] I may say that I have many times observed in my preparations the film of scleroplasm which invests the terminals of both young and old spicules (and which I have endeavoured to represent in figs. 3 and 6), although this is not by any means always visible; in fact, usually is not.

As shown by my figures the scleroblast-mass varies con-

[1] Ijima, however, in a later contribution (16) describes and figures this layer in the oxyhexasters of Rhabdocalyptus capillatus.

siderably in size, and this feature is probably related to the different kinds of spicules to be produced. So few really young stages exist in my material that I am quite unable to say of what types of spicule my figures represent the young stages ; possibly it would be difficult to say under any circumstances, since the young hexact must be an initial developmental stage common to all types, both megascleres and microscleres.

Further, although I am unable to demonstrate it by actual examples,[1] I may say that I think it is highly probable that the initial granule from which in all probability the six rays of the hexactin grow out, is found within a syncytium, and not, as all other siliceous sponge spicules are, in a single cell. In support of this statement I may adduce the following evidence : (a) cell-clusters similar to those represented in fig. 1, are occasionally found in the tissues of the sponge, and are apparently identical with those enveloping young spicules ; (b) the large number of nuclei present in the syncytium containing the young spicules figured confirms the view that more than one nucleus was present at the origin of the spicule ; and (c) this distinction between the modes of origin of hexactinellid and other siliceous sponge spicules is only one of many distinctions which separate the Hexactinellida as a group from other siliceous sponges.

The great extension of the rays of the megasclere type of spicule during the later stages of development in every case causes the centrally-situated syncytial mass to decrease in size and in some cases to vanish, since the scleroplasm is needed for peripheral growth. Ijima suggests that, since in calcareous sponge spicules the scleroblasts ultimately desert the spicule, the syncytium of the hexactinellid spicule possibly does the same, and, as is well known, numerous other authors have often asserted that this desertion does actually

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[1] I searched with the greatest care for a syncytium containing a siliceous granule, spherical or six-cornered, but, as stated in the text, I met with no well-defined stage younger than that figured.

occur in the case of other siliceous sponge spicules. For several reasons I very much doubt if this assumption of the desertion of the siliceous spicule, hexactinellid or otherwise, by the scleroplasm, is justifiable, at least in the majority of cases. It must be remembered that the scleroplasm which builds up the triradiate and other spicules of calcareous sponges differs from the syncytial scleroplasm of siliceous and, indeed, many calcareous spicules, in that it consists of separate scleroblasts, cylindrical or semi-cylindrical in shape (5), which are not united to form a syncytium entirely enveloping the spicule, and which are in consequence free to leave the spicule at almost any period of deposition. On the other hand, seeing that the syncytium which envelops a complex hexactinellid megasclere, e. g. (and the microscleres certainly retain their syncytia) is correspondingly distended and configurated, it is difficult to understand how the syncytium could take its leave as a whole, and it is exceedingly doubtful if the small portions containing nuclear matter separate themselves off from the rest. Personally I believe the scleroplasm of all or, at any rate, most siliceous sponge spicules clings to the spicule as long as it persists, although in many cases it becomes so attenuated as to be invisible. Indeed, the presence of a nucleus is frequently the only visible indication of the existence of a scleroplasmic film enveloping the spicule.

Ijima again suggests the probability that the six rays of the hexactinellid spicule originate as separate sclerites, but supplies no evidence in support of this view, merely mentioning the mode of origin of the triradiates and quadriradiates of Calcarea as possibly presenting an analogous case. That no analogy can be drawn from the mode of development of these calcareous spicules is, I think, sufficiently manifest on remembering that each of the three monaxons of the calcareous triradiate is produced from, and throughout subsequent growth is constantly related to, one of the three cells which " fused " to form the " trefoil " (4, 5), a feature entirely absent in the case of the hexactinellid

spicule, in which no "cells" exist, and in which the nuclei of the undoubted syncytium bear no definite relation to the constituent rays. Moreover, as far as I know, there is no authenticated instance of any siliceous spicule arising by the fusion of initially-separate parts contained in an individual syncytium, though of course it may well be that the hexactinellid spicules are peculiar in this respect as in others. The only ground for believing that the hexact spicule arises by the central fusion of six initially-separate rods that I can imagine is the general similarity which many hexactinellid spicules bear to certain Radiolarian skeletons. In Radiolarians these rays are usually separate, at any rate initially, and in some cases they become fused centrally. If the mode of deposition of hexactinellid rays in the spherical syncytium can be shown to be at all similar to that of Radiolarian spines in the spherical body, a reason certainly exists for supposing that the hexact rays may be deposited initially in a separate condition, but there is no other reason for this supposition that I know of, and personally I believe the six rays of the hexact spicule will be found to emerge from a spherical granule.

Tetractinellida and Monactinellida.

Generalising the large number of statements[1] which have been made by the various authors enumerated in the biblio-

[1] To avoid burdening the text with a somewhat unnecessary account of previous work on the scleroblastic development of siliceous sponge spicules—an account of which both Minchin (4) and Maas (24) have provided an outline—I append a full bibliography of the subject, mentioning after each paper the type or types of spicule, the scleroblastic development of which is described within. I may here add that I have not been able to trace the development of every type of spicule contained in the genera mentioned in the Introduction, and indeed only in one or two cases would this have been desirable (e. g. the development of the rosettes of Esperella), since the development of most types is already known. In fact, so far as I am aware, only in Chondrilla nucula (Tetractinellida), and in Siphonochalina coriacea, Axinella polypoides, Suberites domuncula, Microciona atrasanguinea, Cliona sp., and Ectyon ovoides (Monactinellida), among the sponges

graphy concerning the scleroblastic development of tetra-xonid and monaxonid spicules, we may say without hesitation that the vast majority of the spicules, widely as they may differ among themselves with respect to form and size, arise each as a granule contained within a single scleroblast. The few siliceous spicules which do not thus arise from a single centre, but from several granules contained within the scleroblast (e. g. orthodragmata, Carter's bundles of "tricurvates," etc.) are exceptional, and in every one of these cases the "spicule" consists of several parts throughout its existence. I am not aware of a single instance in which the body of a siliceous spicule-individual is built up by the fusion of originally separate parts, i. e. visible parts, though statements have recently been made to the contrary (see below).

Further, with the exception of those spicules which attain a relatively large size (e. g. the monaxons of Esperella, Ectyon, and Tethya, the large tetracts of Geodia and the spherasters of Tethya) all these spicules throughout their existence as skeletal elements of the sponge-body remain enveloped by the distended substance of the single scleroblast in which they arose; in other words, the nucleus of the scleroblast does not divide (figs. 10—18).

It is needless for me to enter into details in connection with the morphogenesis of each type of spicule; it suffices to say that careful work has proved that in the vast majority of cases each spicule, whatever its ultimate shape, originates as a granule, and only by degrees assumes its final form whilst enveloped by the formative scleroplasm. Also, so far as we know, all growth of the spicule is accretionary and never interstitial, and this fact is constantly to be borne in mind when the identification of young forms of certain types of spicule is in question.

As stated above, the building up of siliceous sponge spicule-individuals by the secondary fusion of separate de-

I have studied, has the scleroplasm associated with the spicules not been hitherto described (see figs. 10—17).

posits is unknown; in other words, no one has yet found siliceous equivalents of the triradiates and quadriradiates of Calcarea. This being the case, it was with some interest that I read an account of this very process which was stated to occur in connection with the spicules of Tethya lyncurium. This account was contained in a paper published by Dr. O. Maas in 1900 (**24**). The exceptional nature of the statements in this paper led me to pay special attention to the scleroblastic development of the spicules in Tethya lyncurium, but, as on a former occasion,[1] I was unable to confirm Dr. Maas' results. Maas makes the following state-

[1] To enable the reader to estimate the value of Dr. Maas' reply (3) I will recall the facts. Minchin in 1898 (**4**) showed that each triradiate spicule of the Ascon sponges which he investigated originated as three separate rods radiating from a common centre, each ray being produced by a pair of cells of the "sextet," and that these rods only secondarily became fused together at their inner extremities to form the triradiate spicule. In the same year (**1a**) and in 1900 (**2**) Maas published papers, each dealing in part with the similar spicules in Sycons. In the latter paper (and with this I am chiefly concerned) Maas described a process of spicule formation as occurring in Sycons which is radically different from that which occurs in Ascons—each triradiate spicule, as a whole, being stated to arise as a single concretion in one mother-cell. At Professor Minchin's suggestion I, during 1903 and 1904, devoted the greater part of a year's work to ascertaining for certain whether the process of spicule formation in Sycons was so fundamentally different from that obtaining in Ascons, as alleged by Maas, and I found, both to Professor Minchin's and my own satisfaction, that the mode of spicule formation in three species of Sycon closely allied to those studied by Maas was identical with that found in Ascons. This being the case I considered that Maas' statements were erroneous, and I ventured to express that opinion—perhaps in too brusque a manner. Dr. Maas in his counter-criticisms says that I obtained anomalous results owing to the method of fixing the Sycons which I adopted—a criticism which applies to Professor Minchin's work as well as my own. I can only reply that Professor Minchin's slides (and my own to a less extent) have been inspected by numerous zoologists, and that no fault has ever been found with them on the score of imperfect histological preservation. Maas' criticism simply proves, what indeed he admits, that he has never seen the three-rod stage of the triradiate spicule, else he would not assume it to be an artefact. Maas again speaks of the initial stages of spicule deposition as if, owing, as he states, to their small size and transitoriness, it were almost impossible to observe them. This is not the case. They are easily to be observed, pro-

ments: (a) the tylostyle spicule arises by the fusion of separate granules present in the substance of the mother-scleroblast; (b) the chiaster spicule arises by the junction at their inner extremities of several rods of silica which are deposited in the scleroblast so as to lie radially in the cell-sphere; and (c) the spheraster usually arises by the fusion of two or more calthrops (each of which arose as a granule contained by a single scleroblast), which serve as a basis on which the rest of the silica is deposited—from which it is inferred that Tethya has tetractinellid affinities. This last statement is illustrated by a somewhat extraordinary figure (his fig. 33) of two closely-apposed attenuated calthrops spicules, each contained in its scleroblast. It is significant that if these three statements be true, then, as before stated, spicule formation in Tethya lyncurium proceeds in a manner different from that hitherto found in any other monactinellid, or, for that matter, tetraxonid sponge.

With regard to the first statement, I entirely agree with Weltner's estimate of its value (**38**). Weltner rightly considers that the several granules have nothing to do with the tylostyle spicule, and that this arises, like other siliceous monaxons, from a single granule which gradually elongates and assumes the form of the adult spicule by continued deposition of silica on its surface. Further Maas' figures of

vided that plenty of suitable material, i. e. a quantity of very young Sycons, is to hand, that this material is prepared in the way described by Minchin, and that the observer possesses sufficient patience to find the comparatively few young stages in his preparations. Maas' remarks about what he supposes to be my ignorance of his own paper and other relevant literature are incomprehensible to me since, besides being entirely mistaken, they are entirely irrelevant to the subject under discussion. Because, as Maas points out, I adopted Minchin's convenient summary ('Zoological Record' for 1901) of his statements concerning spicule formation (and Maas does not dispute the accuracy of Minchin's rendering of his statements) I fail to see that anyone is justified in drawing the curious conclusion that I was unacquainted with the paper which I was criticising! I may add that in my previous paper (**5**) I inadvertently ascribed "tuning-fork" spicules to Clathrina lacunosa.

the cells in connection with the adult tylostyle are quite
incorrect. These never have either an epithelial[1] disposition
or the "syncytial" disposition shown; on the contrary, each
of the several "cells" (i. e. nucleated portions of the syn-
cytium) in connection with the elongated spicule forms a
sloping mound-like mass containing the nucleus, and lies in
close apposition with the spicule, as depicted in my figure of
the Esperella monaxon (fig. 19).

Maas' second statement I believe to be not more valid
than the first. The chiaster, according to my observations,
originates, like the spheraster, as a granule contained within
the cell, and this granule, also like that of the spheraster,
develops rays on its surface (fewer in number[2] and relatively
longer and more uniform in thickness as compared with those
of the spheraster) which become those of the adult chiaster
(figs. 20 c, g). The mother-cell, as Maas states, remains
undivided.

Maas' third statement is also contradicted by my observa-
tions. I can find no evidence whatever that the spheraster
ever passes through a calthrops stage; on the contrary, it
develops in almost exactly the same way as the chiaster.
The initial granule develops numerous radiating rays whilst
quite small (Maas' fig. 7 is quite correct e. g.), and from this
ground form (figs. 20 b, d) the adult spicule is formed
(figs. 20 h, j, k) by the further accretion of silica, and also,
I believe, by the occasional development of fresh rays during
the early stages. As implied above, these rays of the sphe-
raster are more numerous and more conical in form than
those of the chiaster, and these differences alone distinguish
the younger developmental stages; at first indeed it is very

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[1] Maas makes the same mistake in connection with the monaxon spicule of
Sycandra, figuring the half dozen scleroblasts as spherical cells just
touching the surface of the spicule. Scleroblasts never have this arrangement
in connection with spicules or, so far as I know, elsewhere.

[2] Even if, as occasionally may be the case, these spines of the developing
chiaster are four in number, this fact affords no justification for Maas' state-
ments in connection with the spheraster.

difficult to distinguish between them. The development of
the Tethya spheraster in fact is essentially the same as that
described by Keller[1] (**18**) for the spheraster of Chondrilla
nucula. I may further mention that Miss Sollas (**36**) also
failed to find any signs of calthrops, though plenty of
globules, in the larva of Tethya ingalli. The single
scleroblast which contains the initial granule divides as the
spheraster increases in size, with the result that the adult
spheraster possesses several cells; whether any of these are
not division-products of the original mother-cell but are
extraneous in origin, as Maas confidently thinks, I am unable
to say, and I fail to see how it is possible to say without at
least very special inquiry.

With the above criticism on Maas' work in connection with
spicule formation I may include another and minor one.
During my observations of the developing spicules of
Esperella lingua I could never find more than one nucleus
associated with each of the anisochelæ in this species (fig. 18)
whereas Maas (**23**) states that four nuclei occur in connection
with each such spicule in Esperella lorenzi—a statement
which I feel sure is incorrect. I have observed numerous
rosettes in E. lingua, and in every case each anisochele only
possessed one nucleus. In each rosette the anisochelæ were
embedded at their inner extremities in a spherical mass of
protoplasm which contained several nuclei, but all of these
nuclei were quite distinct from those which belonged to the
anisochelæ. The answer to the question as to how the aniso-
chele rosette is formed is not as yet known. Carter (**8**), with
others, supposes that the entire cluster of anisochelæ is
derived from separate silica deposits initially present in one

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[1] Or rather as Keller should have described it. Keller figures the spikes
as arising successively on the surface of the siliceous globule, whereas, in
reality, they arise for the most part simultaneously as small knobs which
gradually assume the pointed form. The spicule is enveloped in one sclero-
blast throughout its existence. The calthrops of Corticium candelabrum
e. g. also originates in the same way—the granule developing four processes
which elongate to form the four rays of the calthrops; also the chiaster,
oxyaster, and sterraster of Geodia gigas.

cell, and even states that he "observed in one cell two inequianchorates together end to end or slightly overlapping each other; but this was in the equianchorate stage." Whether this interpretation of the origin of the rosette is or is not the correct one future inquiry must determine. It is quite certain that the trichites of the ortho- or trichodragmata are produced in one cell and remain in one cell throughout their existence, i. e. the nucleus never divides. Carter also describes and figures the production of several "tricurvates" (toxas) in one cell, the nucleus of which similarly never divides, and several other kinds of dragmata are known. I think it highly probable that subsequent inquiry will prove the Esperia rosette to be derived from a cell-cluster, each of the peripheral cells of which produces an anisochele, the central cells remaining as the central multinucleated "spherical mass of protoplasm" described above.

In conclusion I may remark upon the significant fact that although all sponge spicules arise in the interior of cells, yet in each of the three great groups of sponges—the Tetraxonida, Triaxonida, and Calcarea—spicule formation proceeds on very different lines. In the Tetraxonida the spicule typically arises and continues to exist in one cell, i. e. the cell entirely envelops the spicule; in some cases the nucleus of this cell divides so that a syncytium is formed, and in a few instances several "spicules" are produced in the interior of a single cell. In Triaxonida all the evidence points to the conclusion that a large spherical syncytium containing many nuclei must be formed before the spicule is secreted in its interior, and that the three-dimensioned spicule (the six rays of which arise as outgrowths from an initial granule) is situated in this syncytium, at least for some period of its growth, in much the same way that certain Radiolarian spines are enclosed in the spherical Radiolarian body. Finally in Calcarea, at least the majority of spicules (i. e. with the possible exception of certain monaxons) are formed by the apposition of cells in twos (either by cell-division or cell-junction) and threes (solely by the junction of separate cells) which do not entirely envelop

the spicule as in the other two groups, but merely adhere to the spicule-ray as cylinders or semi-cylinders. These differences as regards the method of spicule formation in the three groups of sponges doubtless possess phylogenetic significance.

SUMMARY.

1. The earliest stages in development of the Hexactinellid spicule are at present unknown, but there exist reasons for supposing that it originates as a granule enclosed by a spherical syncytium in which cell-outlines are absent, and that the six rays of the hexact grow out from this granule.

2. The earliest stage of development yet discovered is the small hexact, the rays of which do not extend to the periphery of the enveloping syncytium.

3. The rays of the hexact elongate, causing the spherical syncytium at first " to present a more or less octahedral shape, with somewhat concave surfaces and with rounded corners " (Ijima).

4. The rays at length extend beyond the spherical contour of the syncytium (the scleroblast mass), the scleroplasm of which, however, persistently adheres to the rays as a thin film, which occasionally includes nuclei.

5. The peripheral growth of the megasclere type of spicule causes the spherical syncytium enveloping the point of junction of the six rays to dwindle and finally to disappear on account of the distension involved. The whole of the microsclere, with the exception of the terminals, remains permanently enveloped by the spherical syncytium.

6. All tetractinellid and monactinellid spicules originate as granules contained within single cells. In a few instances the spicule arises from several granules within the cell and then consists of separate parts (dragmata, for example).

7. All growth is accretionary. There is no well-authenticated instance of a siliceous sponge-spicule being formed by

the fusion of at-first-separate parts—such as occurs in cal-careous sponges, for example.

8. With the exception of very large spicules, the nucleus of the distended scleroblast remains single throughout growth.

9. It is a significant fact that spicule formation proceeds on very different lines in each of the three great groups of sponges—the Tetraxonida, Triaxonida, and Calcarea.

Note.—Unless exceptional opportunities for further work in connection with spicule formation should present themselves that it is intended the present Study shall conclude the series.

LITERATURE.

A. PAPERS NOT CONCERNED WITH THE DEVELOPMENT OF SILICEOUS SPICULES.

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2. ——— "Die Weiterentwicklung der Syconen nach der Metamorphose," 'Zeitschr. f. wiss. Zool.,' Bd. lxvii, 1900.

3. ——— "Ueber die Einwirkung Karbonatfreier und Kalkfreier Salzlös-ungen auf erwachsene Kalkschwämme und auf Entwicklungsstadien derselben," 'Archiv Entwicklung. Org.,' Bd. xxii (4), 1906.

4. MINCHIN, E. A.—"Materials for a Monograph of the Ascons: I," 'Quart. Journ. Mic. Sci.,' N.S., vol. xl, 1898.

5. WOODLAND, W.—"Studies in Spicule Formation: I. Sycon Spicules," 'Quart. Journ. Micr. Sci.,' N.S., vol. xlix, 1905.

B. PAPERS CONCERNED WITH THE DEVELOPMENT OF SILICEOUS SPICULES.

6. CARTER, H. J.—"A Descriptive Account of the Fresh-water Sponges in the Island of Bombay, etc.," 'Ann. Mag. Nat. Hist.' (2), vol. iv, 1849, p. 81 (the opinion is expressed that the spicules originate in the mesogloea).

7. ——— "On the Ultimate Structure of Spongilla, etc.," 'Ann. Mag. Nat. Hist.' (2), vol. xx, 1857, p. 21 (the spicules of Spongilla are recognised as arising each in one cell).

8. Carter, H. J.—"On the Nature of the Seed-like Body of Spongilla; on the Mother-cell of the Spicule, etc.," 'Ann. Mag. Nat. Hist.' (4), vol. xiv, 1874, p. 97 (development of the sigmata, anisochelæ and toxas (several in one cell) of Esperella œgagropila).

9. ———— "Development of Marine Sponges, etc.," 'Ann. Mag. Nat. Hist.' (4), vol. xiv, 1874, p. 321 (development of toxas of Esperella gagropila and Microciona armata).

10. ———— "Further Instances of the Sponge Spicule in its Mother-cell," 'Ann. Mag. Nat. Hist.' (4), vol. xiv, p. 456 (toxas of Esperella œgagropila and Microciona armata in one cell).

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EXPLANATION OF PLATE 7,

Illustrating Mr. W. Woodland's "Studies in Spicule Formation." (VIII.)

HEXACTINELLIDA.

Figs. 3, 5, and 9 are from preparations of Rossella antarctica, Ctr.; the remainder (figs. 1, 2, 4, 6, 7, 8) are from R. podagrosa, Kpk.

Fig. 1 (× 1600 diam.).—Young hexact stages of development. 1 a represents a hexact small in comparison with the enveloping syncytium. The pink hue of the spherical mass of scleroplasm is due to the presence of numerous nuclei which, owing to imperfect preservation of the tissues, are not always visible individually.

Fig. 2 (× 1600 diam.).—Microscleric monodiscohexaster with somewhat dilated extremities. It is not certain whether the extremities have yet assumed their final form, but it is probable.

Fig. 3 (× 2600 diam.).—Adult microscleric holoxyhexaster. Two nuclei have migrated from the central spherical mass of scleroplasm.

Fig. 4 (× 1600 diam.).—Holoxyhexaster, about half-grown.

Fig. 5 (× 1250 diam.).—Adult microdiscohexaster, with several peripherally-situated nuclei ("cells"). Each terminal is invested with a thin film of scleroplasm, though this is not always visible.

Fig. 6 (× 2000 diam.).—Half-grown and adult forms of another variety of microdiscohexaster.

Fig. 7 (× 1600 diam.).—Central portion of an oxydiactine, showing the enveloping scleroplasm with distributed nuclei. The position of the four aborted rays is indicated by the mid-way swellings and axial cross.

Figs. 8 (× 700 diam.), 9 (× 625 diam.).—Hexactines with the enveloping scleroplasm well shown.

MONACTINELLIDA.

Fig. 10 (× 800 diam.).—Tylostyle of Microciona atrasanguinea in its scleroblast.

Fig. 11 (× 1600 diam.).—Acanthotylostyle of M. atrasanguinea in its scleroblast.

Fig. 12 (× 800 diam.).—Tylostyle of Suberites domuncula in its scleroblast.

Fig. 13 (× 1600 diam.).—Oxeote of Siphonochalina coriacea in its scleroblast.

Figs. 14, 15 (× 1600 diam.).—Stylus and oxeote of Axinella polypoides in their scleroblasts.

Figs. 16, 17 (× 1600 diam.).—Acanthoxeote and spiraster of Cliona sp. in their scleroblasts.

Fig. 18 (× 800 diam.).—Anisochela (one of a rosette) of Esperella lingua in its scleroblast.

Fig. 19 (× 800 diam.).—Portion of tylostyle of E. lingua showing two of the several nuclei present in the syncytium enveloping the spicule.

Fig. 20.—Development of the chiaster and spheraster of Tethya lyncurium. *a* and *e* represent the first appearance of the spicule as a siliceous globule. The rays appear on the surface of these globules much earlier in some cases than in others; cf. e. g. figs. *b* and *e*. As stated in the text, it is impossible to distinguish between the very young stages of the chiaster and the spheraster. A comparison of fig. *g* with figs. *h* and *j* shows well, on the other hand, that it is quite easy to distinguish adult chiasters from young spherasters of the same size.